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Correction of Subtle Refractive Error in Aviators (Reprint)

by

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Optimal visual acuity is a requirement for piloting aircraft in military and civilian settings. While acuity can be corrected with glasses, spectacle wear can limit or even prohibit use of certain devices such as night vision goggles, helmet mounted displays, and/or chemical protective masks. Although current Army policy is directed toward selection of pilots who do not require spectacle correction for acceptable vision, refractive error can become manifest over time, making optical correction necessary. In such cases, contact lenses have been used quite successfully. Another approach is to neglect small amounts of refractive error, provided that vision is at least 20/20 without correction. This report describes visual findings in an aviator who was fitted with a contact lens to correct moderate astigmatism in one eye, while the other eye, with lesser refractive error, was left uncorrected. Advanced methods of testing visual resolution, including high and low contrast visual acuity and small letter contrast sensitivity, were used to compare vision achieved with full spectacle correction to that attained with the habitual, contact lens correction. Although the patient was pleased with his habitual correction, vision was significantly better with full spectacle correction, (continued)

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19. **ABSTRACT** (Continued)

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Correction of Subtle Refractive Error in Aviators

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Optimal visual acuity is a requirement for piloting aircraft in military and civilian settings. While acuity can be corrected with glasses, spectacle wear can limit or even prohibit use of certain devices such as night vision goggles, helmet mounted displays, and/or chemical protective masks. Although current Army policy is directed toward selection of pilots who do not require spectacle correction for acceptable vision, refractive error can become manifest over time, making optical correction necessary. In such cases, contact lenses have been used quite successfully. Another approach is to neglect small amounts of refractive error, provided that vision is at least 20/20 without correction. This report describes visual findings in an aviator who was fitted with a contact lens to correct moderate astigmatism in one eye, while the other eye, with lesser refractive error, was left uncorrected. Advanced methods of testing visual resolution, including high and low contrast visual acuity and small letter contrast sensitivity, were used to compare vision achieved with full spectacle correction to that attained with the habitual, contact lens correction. Although the patient was pleased with his habitual correction, vision was significantly better with full spectacle correction, particularly on the small letter contrast test. Implications of these findings are considered.

BEST VISUAL ACUITY (VA) is the goal of ophthalmologic and optometric vision care. Optimal VA also is desired for piloting aircraft in military and civilian environments. Warrant officer candidates for U.S. Army flight school must have uncorrected VA of at least 20/20 in each eye and minimal refractive error (−0.25 D to +1.75 D) [16]. Based on this prerequisite, it is tacitly assumed that most pilots will not require corrective lenses during flight. Spectacles can cause fogging, increased vertex distance, and limited field-of-view when using visual aids such as night vision goggles and helmet mounted displays, particularly when combined with chemical protective masks (2,7–9,17). Ideally, a pilot has 20/20 vision with no requirement for optical correction.

However, the ideal is not always achieved, since refractive error can become manifest or progress after initial qualification for pilot status. Nearsightedness (myopia) can develop in early adulthood (1,5), astigmatism can increase (6), and, as focusing ability (accommodation) decreases with age, hyperopia (farsightedness) may become manifest. Presbyopia, the condition occurring in mid-life when accommodation has decreased sufficiently to warrant correction for near, also can limit near visual performance in flight (7,8). Finding the most suitable correction for refractive error which is compatible with the rapidly developing visual displays and protective masks is an ongoing dilemma.

Several approaches can be taken to obviate the need for spectacle correction in flight. Small amounts of refractive error, particularly that which is low enough to permit 20/20 vision without correction, often are neglected. In addition, contact lenses have been used with considerable success, enabling pilots to wear chemical masks in conjunction with helmet mounted displays (2,7–9,17). Contacts for low amounts of astigmatism (soft toric contact lenses) also offer a promising avenue for correcting mild refractive error. Notwithstanding the efficacy of these approaches, is it sufficient to just meet the standard of 20/20 vision? Should low amounts of refractive error be corrected? Will soft toric lenses offer the stability and refinement of spectacle correction?

In what follows, we address these issues within the context of a clinical case report. An experienced aviator with relatively mild refractive error is described, and several approaches of optical correction are considered. Results of visual evaluation with advanced methods of testing, including high and low contrast VA (3,4) and small letter contrast sensitivity (11–15), are presented in detail. The implications of these findings are considered.

METHODS

Standard clinical techniques, including retinoscopy and subjective refraction, heterophoria and stereopsis testing, tonometry, fundoscopy and biomicroscopy, were used for clinical evaluation. As described in the section that follows, the patient was fitted with a soft contact lens and evaluated 1 mo later with more advanced tests of visual resolution including high and low contrast VA (3) and small letter contrast sensitivity (11–15).

VA was assessed with the Bailey-Lovie acuity charts (3) which have several unique design principles including letters of equal legibility, a logarithmic progression in letter size (0.1 log unit per line), and the same number of letters per line (five) with proportional spacing between letters and lines. These features make task difficulty the same regardless of the level of VA tested. The high contrast (93%) VA chart uses black letters on a white

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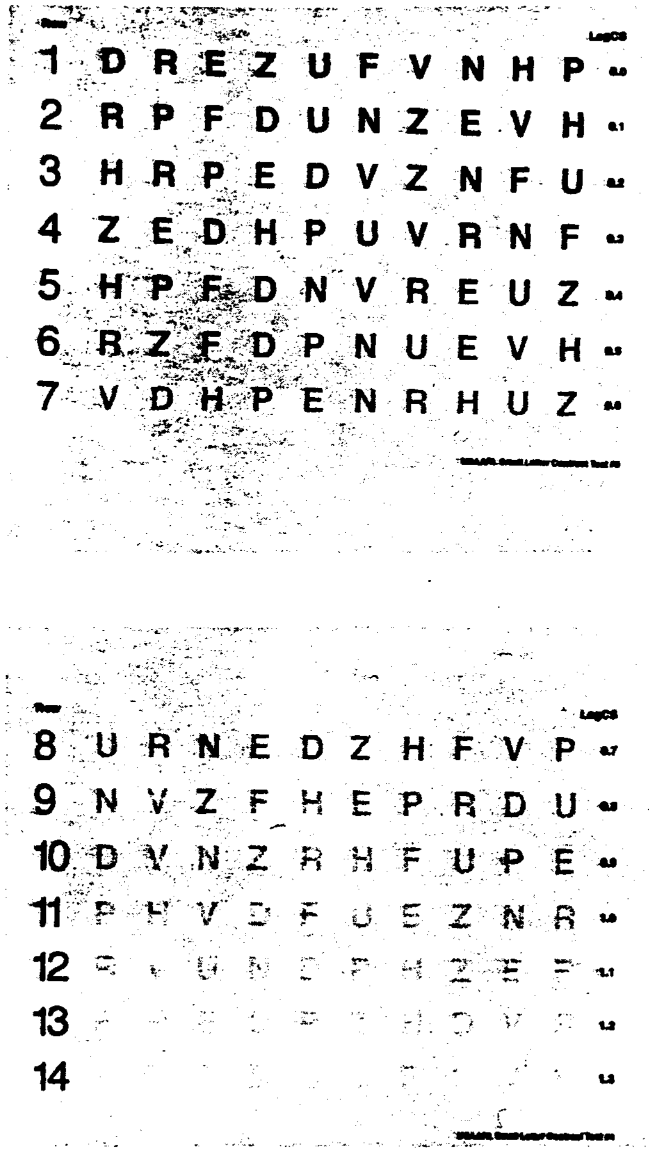

Fig. 1. The Small Letter Contrast Test (SLCT) developed recently in our laboratory [15]. The SLCT has 14 lines of letters with 10 letters per line. Contrast varies by line in 0.1 log steps and credit is given for each letter read correctly (0.01 log unit per letter). Letter size is 20/25.

background, while the low contrast (11%) chart consists of gray letters on a white background. There are two versions of each chart, making it possible to use a different sequence on each trial to discourage learning effects. Credit is given for each letter read correctly (0.02 log units per letter) (4). Vision also was assessed with the recently developed small letter contrast test, or SLCT (15). The SLCT is similar in design to the Bailey-Lovie acuity charts and Pelli-Robson contrast chart (10). However, while VA charts use letters that vary in size, the SLCT uses letters of constant, small size (20/25 Snellen letter size) which vary in contrast (5% to 93%). As shown in **Fig. 1**, the SLCT has 14 lines of letters with 10 letters per line. Contrast varies, by line, in 0.1 log unit steps (0.01 log unit per letter). Research has shown that the SLCT is more sensitive than VA to subtle changes in focus, light intensity, vision with two eyes compared to one, and for identifying visual differences among pilot trainees (11–15).

VA and SLCT were administered in a clinical research laboratory illuminated by fluorescent overhead lighting under rheostat control. The luminance from the middle, white portion of each chart was 100 cd/m^2, and viewing distance was 4 m. The patient was tested with his habitual contact lens correction and with full spectacle correction, as described in subsequent sections. Different VA and SLCT letter sequences were used on successive trials to discourage learning effects. Credit was given for each letter read correctly (0.02 log unit per letter for VA; 0.01 log unit per letter for SLCT).

Case Report

A 41-year-old, white male in good general health presented for a routine eye exam. The patient was an experienced aviator who wore glasses for flying. He expressed an interest in wearing contact lenses. He had no personal or family history of ocular or systemic disease. Clinical evaluation revealed that his binocular vision and ocular health were within normal limits.

Upon examination the patient's spectacle correction was: RE plano − 0.75×078; LE plano − 1.25×084. Refraction to best visual acuity revealed a slight shift toward hyperopia: RE +0.25−0.50×086; LE +0.50−1.50×086. Such a change is not uncommon in this age category since, as accommodative amplitude decreases with age, more plus (or less minus) is manifest in the distance correction. In this particular case, the hyperopic change was fortuitous since the spherical equivalent refractive error (sphere + $\frac{1}{2}$ cylinder component) had shifted toward emmetropia (i.e., no correction) enabling the patient to see better at distance without correction.

The hyperopic shift and low degree of astigmatism in the right eye suggested that the patient may see well enough under most conditions without optical correction. Indeed, his visual acuity in the right eye was 20/20 without correction. To correct the greater degree of astigmatism in the left eye (spherical equivalent = −0.25D), a soft toric contact lens was selected "off-the-shelf" from current supply. Clinically, the intent was to provide a monocular contact lens correction that would be comparable visually but cosmetically superior to the patient's spectacle correction.

Initial evaluation showed that contact lens fit, comfort, and vision were within normal limits. The contact lens was dispensed for daily wear, and the patient gradually increased his daily wearing time to approximately 12 h·d^{-1}. At follow-up, he had worn the lens successfully for 1 mo. The corneal physiological response to daily soft lens wear was within normal limits, and vision was at least 20/20 in each eye. The patient had no complaints and was quite pleased with this mode of correction.

RESULTS AND DISCUSSION

While the patient in this report had no immediate intent of wearing his monocular contact lens correction for pilot duty, the case raises several pertinent issues regarding the use of optical correction for aviation and related fields. Is the level of vision achieved with the soft toric contact lens adequate for piloting aircraft? Would spectacle correction provide better vision? Is it necessary

TABLE I. REFRACTIVE ERROR AND VISUAL RESOLUTION.

	Full Spectable Correction		Habitual Correction	
	Right Eye	Left Eye	Right Eye (no lens)	Left Eye (soft toric contact lens*)
Lens Power	+0.25 with −0.50 × 0.86	+0.50 with −1.50 × 086	plano	+0.25 with −1.25 × 070
High Contrast VA	20/13.7	20/14.4	20/15.7	20/18.1
Low Contrast VA	20/17.7	20/16.5	20/22.8	20/24.9
Small Letter CS (logCS)	1.27	1.28	1.06	0.96

* An axis of 70° was chosen to compensate for counterclockwise rotation of the contact lens on the patient's eye.

to correct the small amount of astigmatism the patient showed in his right eye? These questions were addressed by carefully comparing the level of vision the patient achieved with full spectacle correction to that attained with the monocular contact lens correction.

Table I shows a comparison of the patient's visual resolution with full spectacle correction and his habitual correction (RE: no lens, LE: soft toric contact lens). As noted earlier, testing was conducted with high and low contrast VA and with the Small Letter Contrast Test (SLCT) which uses small letters varied in contrast rather than size. Although VA was better than 20/20 in each eye with habitual correction, vision was improved with full spectacle correction, particularly on the SLCT. This is exemplified in **Fig. 2** which shows the patient's VA and SLCT scores expressed as standard deviations below the mean for 16 fully corrected, normal observers [15]. While both high and low contrast VAs were somewhat reduced with habitual correction, values were still within normal limits. In contrast, SLCT scores were more than 2 SD below normal.

Fig. 3 shows the magnitude of visual improvement with full spectacle correction compared to habitual correction (RE: no lens, LE: soft toric contact lens). Values are expressed as lines of letters on each vision chart with each line representing 0.1 log unit (antilog of 0.1 = 1.26× or 26% per line). Whereas full correction afforded only ½ to 1 line improvement in high contrast VA, there was a 2-3 line improvement on the SLCT.

The improvement in visual resolution with full spectacle correction, indicated by the slight increase in VA and larger increase on the SLCT, may be significant operationally, particularly in aviation environments. Pilots require precise visual information to make critical decisions under time-limited conditions. The 2–3 line reduction in SLCT score indicates that the contrast of a small target would have to be increased 0.2–0.3 log units (60–100%) to be detected with habitual correction at the same range as detection occurs with spectacles. In some circumstances, such a difference could be critical for discrimination of friend or foe, and ultimately, save lives. However, the results reported here represent only one case, and must be considered within the context of other, competing factors such as the incompatibility of spectacles with helmet mounted optical devices and chemical protective masks. Moreover, the patient was quite pleased with his monocular contact lens correction and, in certain cases, contact lenses provide equal or better vision than spectacles.

The results do indicate that simply satisfying the standard of 20/20 vision does not fully characterize the level of visual resolution achieved. Adjunctive tests administered with precise scoring techniques, including high and low contrast VA and the small letter contrast test, can enhance significantly the sensitivity and reliability of clinical vision assessment.

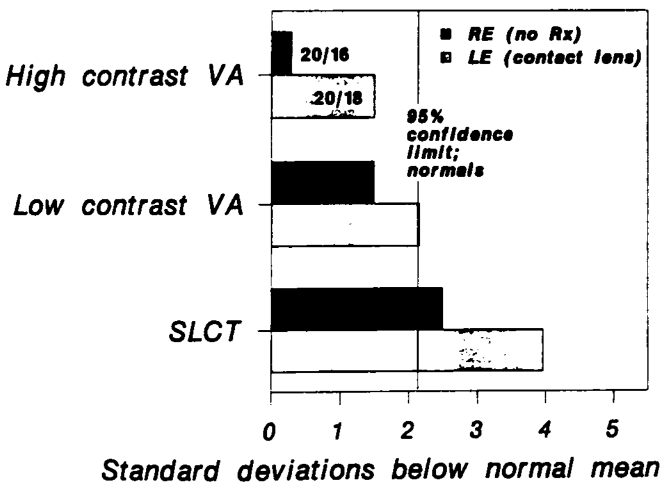

Fig. 2. High and low contrast VA and SLCT scores are plotted for the patient's right and left eyes. Values are expressed as standard deviations below the mean score for 16, fully corrected observers with normal vision (15). During testing, the patient was uncorrected in his right eye (+0.25–0.50 × 086), but wore a soft toric contact lens in his left eye.

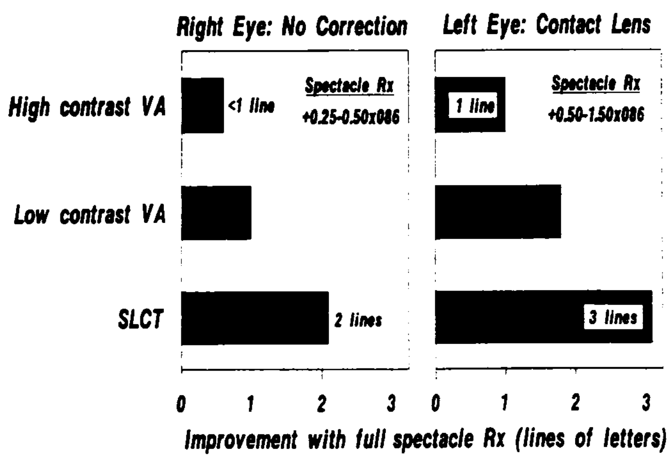

Fig. 3. The visual improvement the patient achieved with full spectacle correction compared to his habitual correction (RE: no lens, LE: soft toric contact lens). Improvement is expressed as lines of letters on each vision test (0.1 log unit per line). The full spectacle correction for each eye is shown in the upper right corner of each graph.

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